Electrode Structure for Measuring Electrical responses from the Human Body

The present invention relates to an electrode structure according to the preamble of Claim 1.

The invention also relates to a measuring cap and a manufacturing method.

According to the prior art, measurements made from the surface of the head in particular are made using silver electrodes for measuring electrical responses, for example, in TMS (transcranial magnetic stimulation) tests, in which an electromagnetic pulse is directed to the brain and the response it creates is measured using electroencephalograph (EEG) measuring equipment. In practice, electrically polarizing interfaces arise between the different materials in the silver electrodes according to the prior art and lead to interference signals that diminish the accuracy of the measurement.

The silver electrodes are chloridized, in an attempt to eliminate this phenomenon. Despite this measure, satisfactory results are not always achieved. As chloridization only affects the surface of the electrode, it is easily removed by wear or, for example, by unintentionally scratching the electrode. Chloridization must be performed regularly between measurements, leading to additional work and preventing continuous use of the electrodes.

In measurement caps according to the prior art, the electrode structures become detached easily during washing and are difficult to reattach.

The invention is intended to eliminate the defects of the state of the art disclosed above and for this purpose create an entirely new type of electrode structure.

The invention is based on the fact that the smaller the electrode, the smaller the electrical currents induced by a magnetic stimulation pulse, which fact is exploited in the invention by making the electrode thin in the thickness direction of the electrode structure, and by equipping the electrode structure with holes and locating the electrode at the edge of the hole, so that its longitudinal axis is essentially parallel to the plane of

the measurement subject.

One preferred embodiment of the invention is, on the other hand, based on the realization that, if an electrode made from silver/silver-chloride is used, the electrode surface will also remain essentially unaltered, even if the electrode wears or is scratched, because the electrode consists throughout of the same material.

A third preferred embodiment of the invention is based on using small electrodes made from silver-chloride pellets, which can be installed in a measurement hood using a snap-fit attachment.

More specifically, the electrode structure according to the invention is characterized by what is stated in the characterizing portion of Claim 1.

The measuring cap according to the invention is, in turn, characterized by what is stated in the characterizing portion of Claim 12.

The method according to the invention is, in turn, characterized by what is stated in the characterizing portion of Claim 16.

Considerable advantages are gained with the aid of the invention.

The solution according to the invention permits electrical responses to be measured during, or a short time after the magnetic pulses produced by the magnetic stimulators, typically after 1 - 5 ms, even after a powerful magnetic pulse, particularly if the solution according to the invention is used in conjunction with magnetic stimulation simultaneously with suitable EEG equipment.

The electrode structure according to the invention forms a stable electrical contact between the person being measured and the electrode. The attachment construction of the electrode is compact in size, thus permitting a TMS coil to be placed close to the surface of the head. The coil's effective distance is about 30 mm and the effective electrical field induced diminishes rapidly as the distance increases. The solution

according to the invention permits the coil to be placed closer to the point it is wished to affect. With the aid of the invention, it is possible to create in the brain a TMS-induced electrical field that is typically 5 - 30 % stronger than when using thicker electrode attachment constructions. The value of a 5 - 30 % stronger electrical field is calculated from a distance difference of 2 - 3 mm, i.e. if the electrode's attachment were to be 2 - 3 mm thicker, the electrical field induced by TMS in the tissue would be correspondingly weakened.

According to one preferred alternative of the invention, the electrode structure 10 is entirely non-magnetic, i.e. the magnetization of all the structural materials is very small. For example, this is a great advantage and even an essential requirement in measurements made in connection with an MEG (magnetoencephalography) device. MEG compatibility is, in turn, a great advantage in laboratories and in applications, in which TMS and EEG, as well as MEG measurements are used. A non-magnetic structure is also very important if EEG measurements are made during MRI imaging (Magnetic Resonance Imaging), for example, in connection with FMRI (Functional Magnetic Resonance Imaging) tests. The electrode structure (10) is constructed in such a way that a special tool is needed to detach it, while, in addition, the construction protects the brittle silver-chloride electrode (1) from impacts, scratching, and wear.

The electrode structure according to the invention does not require chloridization, and thus interfaces that hamper measurements are not created in the electrode structure. When the electrode wears, its electrical properties remain unchanged.

In addition, the measurement point on the skin of the test person can be cleaned after the attachment of the electrode, as there is a sufficiently large hole (6) in the electrode structure.

The small size and compact shape of the electrode prevents the magnetic stimulation coil from inducing strong electromotor forces in the electrode and thus reduces the creation of eddy currents caused by the electrical fields.

In the following, the invention is examined with the aid of an example of an embodiment

according to the accompanying drawings.

Figure 1 shows a bottom view of one electrode structure according to the invention.
Figure 2 shows a side view of the electrode structure according to Figure 1.
Figure 3 shows a cross-sectional side view along the line A-A of the sensor according to the invention.
Figure 4 shows a cross-sectional view along the line B-B of the electrode structure according to Figure 2.
Figure 5 shows an exploded perspective view of the electrode structure according to the invention.
Figure 6 shows a perspective view of the electrode structure according to the invention.
Figure 7 shows a perspective view of electrode structures according to the invention, located on a measuring cap.

According to Figure 1, the electrode structure according to the invention is examined from beneath, in other words, from the direction of the measurement subject. The electrode structure 10 includes a body piece 2, from which a measuring lead 4 protrudes. Electrical contact from the measurement subject, typically a person's scalp, to the electrode material, is formed through the hole 6, with the aid of an electrically conductive past. According to the figure, the electrode structure 10 is essentially disc-shaped.

Figure 2 shows the locking piece 3 connected to the body piece, by means of which the measuring cap described later is locked between the body piece and the locking piece. The locking piece 3 is located on the outer surface of the electrode structure, if the inner surface is defined as the measuring surface, for example, the scalp.

Figure 3 shows the construction of the measuring electrode 10 in greater detail. The measuring opening 6 extends through the entire structure and the piece 3 locks onto the body piece 2 with the aid of locking lugs. The electrode 1 made from silver/silver-chloride is located at the very edge of the opening 6, thus forming a contact with the contact paste (not shown) in the hole 6. The electrode 1 is typically connected to the measuring lead 4 with the aid of a silver connector lead 5. The connection of the

electrode 1, which the connector lead 5 also permanently forms part of, to the measuring lead 4 demands special measures, for example, there must be no silver/silver-chloride spatters in the silver wire 5 and the soldering of the measuring lead 4 and the silver wire must not touch the electrode 1, as the hot solder will melt the Ag-AgCl mass, ?? which? is made by sintering, and form an interface with it, which may, in turn, cause interference in the measuring situation. The electrode pellet 1 typically has a cylindrical shape, so that its longitudinal axis is parallel to the measuring surface. This alignment gives the electrode structure 10 a flat dimension, which is as small as possible, between the measuring surface 13 and the outer surface. The dimension of the electrode 1 in the thickness direction of the electrode structure 10 is, according to the invention, small, preferably less than 5 mm, and most preferably less than 2 mm. The term thickness of the electrode 1 refers to its dimension in the direction of the thickness of the electrode structure 10, in other words, for example, the left-to-right dimension in Figure 3.

In this case, the term measuring situation refers, for example, to a measurement made after a stimulation pulse. Non-magnetic plastic, which is dry-machined, is used as the raw material for the plastic components 2 and 3. This is done, because the machining liquid used in the machining centre may contain magnetic materials, which would hamper measurement.

A particularly advantageous result is achieved, if a magnetization value less than that given below is achieved.

If the electrode construction is oscillated with an amplitude of about 5 cm at a distance of 3 cm from a sensor measuring the density of the magnetic flux, the peak value of the density of the magnetic flux caused by the oscillation of the electrode 10 should be less than 80 femtotesla in a shielded enclosure, in which there is a dc field of 30 nanotesla.

According to Figure 4, the cross-section of the body piece 2 is essentially circular. A curved opening arrangement, in which the locking piece 3 is locked, is made in the circular piece 2. The electrode 1 extends to the hole 6 in the electrode structure. According to the figure, the brittle electrode 1 is tightly inside the body structure 2.

Figures 5 and 6 show a perspective view of additional details of the invention. Thus, the upper surface of the locking piece 3 is essentially annular in shape and forms a uniform flat surface on the side opposite to the measuring surface.

According to Figure 7, the electrode structures are placed at regular intervals in the cap 7 and the cap is placed around the skull.

The measuring leads of the measuring cap are wound into a tight, preferably spiral bundle, in order to reduce interference. In addition, according to a preferred embodiment of the invention, the earth and reference electrode leads of the measuring cap are wound tightly together, to reduce interference. Interference can be further reduced by running the measuring leads from the electrodes towards the front of cap 11.

Within the scope of the invention, the electrode structure can deviate from a disc-like shape and flat angular and elliptical shapes too are quite possible. The use of curved surfaces between the body 2 and locking 3 pieces achieves a more even locking effect.

According to one preferred embodiment of the invention, the electrode 1 of the electrode structure 10 is so small in size that a cross-section through any plane at all of the electrode 1 will have a surface area of less than 15 mm^2, more preferably of less than 4 mm^2.

The small size is important, in order to reduce the electrical field caused by induction and the eddy currents arising in the electrode 1.